MECHANICAL ENGINEERING

DIMEAS/Energy Center - Modelling the integration of offshore renewable energy generation and e-fuels

Funded By	Dipartimento DIMEAS Centro Interdipartimentale Ec-L
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Context of the research activity	Achieving full independence from fossil fuels in the European energy system requires to enhance our ability to access all renewable energy sources (RES) available. The exploitation of offshore-RES (ORES) by mean of floating offshore wind turbines (FOWT), floating photovoltaic (FPV) and wave energy (WE) is crucial to achieve a socially and environmentally sustainable energy transition. In fact, such technologies make it possible to minimise the land use for energy production, as well as to reduce the visual impact, thereby increasing social acceptability. Nevertheless, an increasingly high penetration of power generation from variable-RES (VRES) requires for appropriate plants and technologies for the management and storage of unpredictable and non-dispatchable electricity fluxes. In such a framework, synthetic fuels (or e-fuels) – primarily hydrogen – are emerging strongly thanks to: (1) the possibility of producing them at times of overproduction from VRES; (2) their ability to decarbonise “hard-to-abate” industrial processes and economic sectors. Such energy carriers, once they have been produced, can be stored and used for several applications, included medium- to long-haul mobility. Several studies and policy reports foresee a great increase the global hydrogen and e-fuels demand in the coming decades. Research on both offshore RESs and e-fuels production is needed to favour technological progress and the large-scale penetration of these solutions. In particular, energy system modelling is required to explore the synergies, criticalities and potential of the combined operation of these technologies.
	The key goal of the PhD activity is to develop a model of the Italian energy system in order to study the interaction of offshore renewables and technologies for the production of e-fuels (short-term model), as well as the potential for their development (long-term, or capacity expansion, model). A list of activities to be developed within the PhD programme is presented as follows:

Objectives	1. The bottom-up modelling of the investment and operation & maintenance costs of offshore renewable technologies (FOWT, FPV, WEC and the related offshore cables), as well as of the technologies and processes for the generation, management and storage of e-fuels. The activity aims at producing a set of technologies cost functions which relates the cost of the plants to their size and other design parameters, to be used as an input for energy models. 2. Adaptation of existing long-term and short-term energy modelling frameworks to the use of technologies cost functions. 3. Modelling of the Italian energy system with a regional-based approach, able to take into account transfer capacities of the Italian power system. Mixed integer linear programming techniques such as Calliope, OSeMOSYS and PyPSA could be taken into account. The developed models should be aimed at developing capacity expansion and investment planning while taking into account macro-issues related to the power balance of the grid. 4. Quantitative estimation of the potential for the development of ORES in the Italian seas, also in view of different approaches to the maritime spatial energy planning (MSEP) of the Country, and development of a technique for the competitive optimisation of the different available technologies, in view of available areas, distance from the coast and other decision parameters. 5. Development of future energy scenarios as a function of: - Different forecasts on the evolution of the Italian energy demand, with special regards to the demand of e-fuels and of the diffusion of the technologies for their final use. - Evolving cross-sectoral integration for maximising the penetration of VRES. - Possible cost trends of the technologies for the exploitation of ORES. - Possible cost trends of the technologies and processes for the production, management and storage of e-fuels. - Public policies related to the planning and deployment of the above mentioned technologies. The final aim is to derive a spatially-resolved energy system of Italy (by means of multiple interconnected nodes) to investigate the contribution of ORES and e-fuels in highly decarbonised scenarios. References: - IRENA, “Geopolitics of the Energy Transformation. The Hydrogen Factor,” 2022. - Hydrogen Council, “Path to hydrogen competitiveness. A cost perspective,” 2020. - S. Pfenninger and B. Pickering, “Calliope: a multi-scale energy systems modelling framework,” J. Open Source Softw., vol. 3, no. 29, p. 825, 2018, doi: 10.21105/joss.00825. - M. Howells et al., “OSeMOSYS: The Open Source Energy Modeling System. An introduction to its ethos, structure and development.,” Energy Policy, vol. 39, no. 10, pp. 5850–5870, 2011, doi: 10.1016/j.enpol.2011.06.033.

Skills and competencies for the development of the activity	- Excellent knowledge of the Python environment. - Knowledge in the main storage and offshore renewable energy generation technologies. - Experience in energy system modelling.